

STATUS OF NUCLEON RESONANCES WITH MASSES

$$M < M_N + M_\pi$$

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We discuss different interpretations of the peaks observed a few years ago by Tatischeff *et al.* ¹ in the missing mass spectra of the reaction $pp \rightarrow \pi^+ pX$, which were declared as new excited nucleon states with small masses. A study of the possible production of such states in the process $\gamma p \rightarrow \pi^+ N^* \rightarrow \pi^+ + \gamma \gamma n$ by analysing the invariant mass spectrum of $\gamma \gamma n$ is proposed. It is shown that the experimental data obtained at MAMI-B allows to analyse this process and to get information about an existence of excited nucleon states with small masses.

A few years ago three narrow bumps have been observed in missing mass spectra of the reaction $pp \rightarrow p\pi^+ X$ by Tatischeff *et al.* ¹ at $M_X = 1004, 1044$, and 1094 MeV. These bumps were interpreted as new nucleon resonances N^* . The values of masses $M_X = 1004$ and 1044 MeV are below $m_N + m_\pi$ and so these states can decay with an emission of photons only. If they decay into γN then these resonances have to contribute to the Compton scattering on nucleon. However, the analysis ² of the existing experimental data on this processes completely excluded such N^* as intermediate states in the Compton scattering on the nucleon.

In Ref. ³ it was assumed that these states belong to the totally antisymmetric $\underline{20}$ -plet of the spin-flavor $SU(6)_{FS}$. Such a N^* can transit into nucleon only if two quarks from N^* participate in the interaction. Then the simplest decay of N^* with the masses 1004 and 1044 MeV is $N^* \rightarrow \gamma \gamma N$. This assumption could be checked, in particular, by investigating the reaction $\gamma p \rightarrow \gamma X$ or $\gamma p \rightarrow \pi X$ in the photon energy region about 800 MeV.

Another interpretation of the states found in work ¹ was suggested in Refs. ^{4,5}. In these works the reaction $pd \rightarrow p + pX_1$ has been studied with the aim of searching for supernarrow dibaryons (SND), decay of which into two nucleon is forbidden by the Pauli exclusion principle. Three peaks have been observed in invariant mass spectra of pX_1 states at $M_{pX_1} = 1904 \pm 2, 1926 \pm 2$, and 1942 ± 2 MeV (see Fig.1a). The analysis of the angular distribution of the protons from the decay of pX_1 states showed that the peaks found can be explained as manifestation of the SNDs. Additional information about the

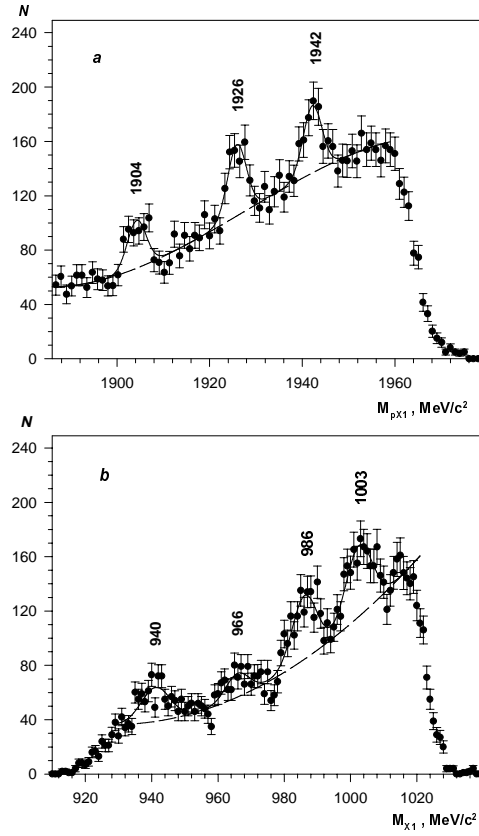


Figure 1. The invariant mass M_{pX_1} (a) and missing mass M_{X_1} (b) spectra

nature of these states have been obtained by analysing the missing mass M_{X_1} spectra. If the observed state is a dibaryon decaying mainly into two nucleons then X_1 is a neutron and M_{X_1} has to be equal to the neutron mass m_n . If the value of M_{X_1} , obtained from experiment, differs essentially from m_n then $X_1 = \gamma + n$ and the found state is SND.

Fig.1b demonstrates the missing mass M_{X_1} spectrum obtained in Refs ^{4,5}. As is seen from this figure, besides the peak at the neutron mass, which caused by the process $pd \rightarrow p + pn$, the resonancelike behavior of the spectrum is

observed at 966 ± 2 , 986 ± 2 , and 1003 ± 2 MeV. These values of M_{X_1} coincide with the simulated ones and differ essentially from the neutron mass. Hence, the dibaryons found are really SNDs.

It should be noted that the peak at $M_{X_1} = 1003 \pm 2$ MeV corresponds to the bump observed in Ref ¹. Taking into account the found connection between SNDs and resonancelike states X_1 , authors of the works ^{4,5} assumed that the peaks from Ref ¹ at 1004 and 1044 MeV are not the exited nucleons, but they are the resonancelike states $X_1 = \gamma + n$ caused by possible existence and decay of the SNDs with the masses 1942 and 1982 MeV. Such X_1 are not real resonances and cannot give contribution to the Compton scattering on the nucleon.

However, a SND can also decay into NN^* . Unfortunately, the experiment ^{4,5} could not unambiguously discriminate an exited nucleon from X_1 state. To clarify this question we propose to study the exited nucleon production in the process

$$\gamma + p \rightarrow \pi^+ + N^* \rightarrow \pi^+ + \gamma\gamma n \quad (1)$$

by analysing the invariant mass spectrum of the $\gamma\gamma n$ at the incident photon energy from 537 up to 817 MeV. The data on this process can be obtained from the experiment on the radiative π^+ meson photoproduction from the proton, which has been carried out at MAMI-B. In this experiment γ , π^+ , and n were detected, so we have enough data to reconstruct the invariant mass of the $\gamma\gamma n$ from 985 up to 1075 MeV. The lowest value of $M_{\gamma\gamma n}$ is due to the threshold of the final photon energy (15 MeV) and the highest one corresponds to the sum of masses of the neutron and π^0 meson.

The main background processes are $\gamma p \rightarrow \pi^0 \pi^+ n$ and $\gamma p \rightarrow \pi^0 \pi^0 \pi^+ n$. To suppress the contribution of the double pion photoproduction, we will consider the invariant mass of two photons $M_{\gamma\gamma} < 110$ MeV. As the π^+ meson and N^* must fly in the same plain, we have an additional condition on the difference of pion and N^* azimuthal angles: $160^\circ < |\phi_{\pi^+} - \phi_{N^*}| < 200^\circ$. This condition allows to suppress the contribution of the triple pion photoproduction.

The results of the simulation of the N^* production in the process (1), at the conditions of the radiative π^+ meson photoproduction from proton experiment and for an exposition time of 100 hours, are shown in Fig.2. The calculations obtained without any cuts are presented in Fig.2a. Fig.2b demonstrates the final result after both cuts. As is seen from this figure, the background can be well suppressed and, if N^* states exist, they would be well recognizable.

In the experiment on radiative π^+ meson photoproduction we had about 1000 hours of exposition time. As result, we expect to get about 600, 3500, and 12000 events for the exited nucleon states with the masses 986, 1004, and

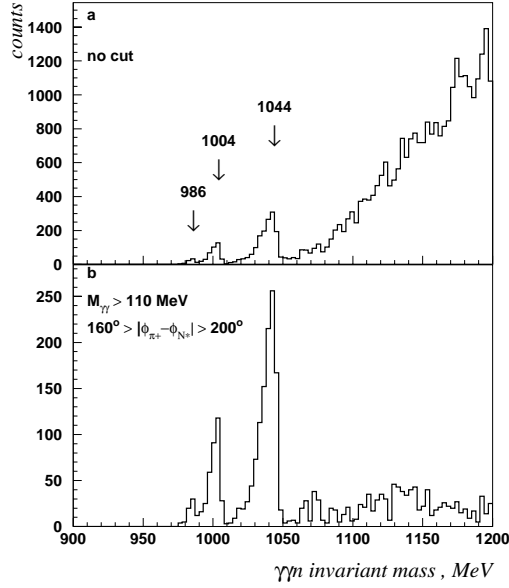


Figure 2. Invariant mass spectra of $\gamma\gamma n$. (a) – without any cuts; (b) – taking into account conditions $M_{\gamma\gamma} < 110$ MeV and $160^\circ < |\phi_{\pi^+} - \phi_{N^*}| < 200^\circ$.

1044 MeV, respectively. So this experiment can give important information about possibility of existence of excited nucleon states with small masses.

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